Concussion Burden, Recovery and Risk Factors in Elite Youth Ice Hockey Players

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Abstract:

Objective: To examine rates of concussion and more severe concussion (time loss greater than 10 days) in elite 13-17 year old ice hockey players.

Methods: This is a prospective cohort study (Alberta, Canada). Bantam (13-14 years) and Midget (15-17 years) male and female elite (top **20**% by division of play) youth ice hockey players participated in this study. Players completed a demographic and medical history questionnaire and clinical test battery at the beginning of the season. A previously validated injury surveillance system was used to document exposure hours and injury during one season of play (8 months). Players with a suspected ice hockey-related concussion were referred to the study sport medicine physicians for assessment. Time loss from hockey participation was documented on an injury report form.

Results: Overall, 778 elite youth ice hockey players (659 males, 119 females; aged 13-17 years) participated in this study. In total, 143 concussions were reported. The concussion incidence rate (IR) was 17.60 concussions/100 players (95% CI; 15.09, 20.44). The concussion incidence rate (IR) was 1.31 concussions/1000 player-hours (95% CI; 1.09, 1.57). Time loss greater than 10 days was reported in 74% of cases (106/143) and 20% (n=28) had time loss of greater than 30 days.

Conclusion: Concussion is a common injury in elite youth ice hockey players. In this study population, a large proportion of concussions (74%) resulted in a time loss of greater than 10 days, possibly reflecting more conservative management or longer recovery in youth athletes.

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Introduction:

Concussion is a brain injury.[1] Concussion is one of the most commonly occurring injuries in youth sport and recreation and the most frequently reported injury in youth ice hockey.[2] The majority of individuals recover from concussion in 10-14 days.[3] However, in youth who present to the emergency department, up to 30% remain symptomatic one month following concussion.[4 5] Notably, this estimate includes concussion related to all causes and likely represents a more severe cohort, as not all individuals who sustain a sport-related concussion will present to the emergency department. Similarly, estimates for recovery times of individuals seen at specialty clinics will be greater than overall recovery rates, as only those individuals who have not recovered in the initial period following injury will present to these clinics. Therefore, concussion recovery should be evaluated prospectively in a community-based cohort to encompass the entire spectrum of injury severity and to account for population-specific characteristics.

Concussion incidence and recovery have been evaluated in collegiate populations, but less evidence is available for youth.[6 7] While the majority of young athletes recover and return to sport, some individuals are left with persisting symptoms that affect function and their ability to participate in sport and activities of daily living.[4] Identification of risk factors for concussion is imperative.

The majority of Canadians between 15 and 19 years of age report participating in sport.[8] Ice hockey is a popular sport, with over 250,000 Canadians ages 12-17 years participating in ice hockey.[9] The majority of participants are male.[8 9] Ice hockey is

classified as a collision sport, with body checking being allowed in many Canadian leagues.[9] Risk of concussion has been reported to be highest among individuals participating in collision sports (e.g., ice hockey, rugby, football).[6 7 10 11] In a meta-analysis, the rate of concussion in youth ice hockey are reportedly 1.20 (95% CI; 1.00, 1.31) per 1000 athlete exposures.[11] This rate was second only to rugby in individuals under the age of 18 years.[11] Therefore, there is an inherent risk of injury associated with ice hockey participation, including the potential for long-term impairments and disability.

Historically, there has been concern regarding underreporting of concussion.[12] Thus, it is important to evaluate concussion rates in youth ice hockey prospectively using valid surveillance techniques, with particular attention to those with a longer-term recovery. The primary objective of this study is to evaluate the incidence rate of concussion and concussion with longer-term recovery in elite youth ice hockey players aged 13-17 years. Secondary objectives of this study were: 1) To evaluate risk factors for concussion and longer-term recovery (i.e., time loss of greater than ten days) in elite youth ice hockey players aged 13-17 years, to inform the optimization of prevention and intervention strategies; and 2) To determine if there was a difference in time to medical clearance to return to sport between males and females.

Methods:

This is a prospective cohort study completed during the 2011-2012 ice hockey season.

Participants:

Male and female youth ice hockey teams were eligible for participation if they were in the top two levels of play ("AA" and "AAA") and in the Bantam (13-14 years of age) and Midget (15-17 years of age) age groups in Calgary and Edmonton, Canada. These teams represented the most elite 20% of players in the eligible age groups. The male players in this study played in leagues that allowed body checking, whereas the female leagues did not allow body checking. **Players who had sustained an injury or had a chronic illness that prevented full participation in ice hockey prior to the beginning of the season were excluded.**

Hockey associations were informed of the study objectives and once the associations' permission had been granted, their team coaches and therapists were approached for recruitment. Following coach consent, individual players and parents were invited to participate. Both parental consent and player assent were obtained prior to participation. This study was approved by the Conjoint Health Research Ethics Board at the University of Calgary, Calgary, Alberta, Canada (Ethics ID 24026) and the University of Alberta, Edmonton, Alberta, Canada (Ethics ID 00003490).

Procedures:

Baseline questionnaires, including demographic, medical, and injury history (including reports of previous concussion), were collected upon study entry. Each participant then completed a baseline testing session that included evaluation of a variety of test domains. Baseline measures included the Sport Concussion

Assessment Tool 2 (SCAT2), Immediate Post-Concussion Assessment and Cognitive Test (ImPACT) and Behaviour Assessment System for Children, Second Edition (BASC-2). A battery of clinical cervical and vestibular measures and a computerized test of dynamic visual acuity were also administered in the Calgary cohort. Detailed characteristics of these measures are reported elsewhere, as the focus of this paper is concussion burden, risk factors, and recovery in elite youth ice hockey players.

A previously validated injury surveillance system was used to prospectively collect exposure and injury data throughout the 2011-2012 playing season.[13] Each participating team had a team therapist who collected weekly exposure information. This included data regarding games, dryland training, and practices. Missing individual exposure data were imputed based on mean team exposure values. In the case of missing team data, exposure was imputed based on mean age group and sex specific exposure values. Previous evaluation of weekly exposure imputation techniques has identified this as an appropriate and valid method.[14] Team therapists also collected concussion data using standardized injury report forms (IRF).

Concussion:

At the time of a suspected concussion (based on team therapist assessment or athlete/parent referral) participants were referred to a study sport medicine physician for follow-up. Concussions were diagnosed according to the definition and recommendations of the consensus statement on concussion in sport.[15] Each

concussion was individually medically managed as indicated by clinical assessment findings and according to the standard of care, including an initial period of rest followed by a standardized protocol of exertion prior to medical clearance to return to play.[15]

Time loss was determined as the number of days to medical clearance to return to sport. Clinical follow-up data (e.g., medical charts) were the most accurate measure of medical clearance to return to play and provided the primary source of time loss information. A study physiotherapist was in continual communication with injured participants to ensure that follow-up visits with study physicians were completed at the time point of completion of the return to play protocol. In the event that an individual failed to return for their final follow-up visit and had not yet initiated the return to play protocol, seven days were added to the last date of follow-up, as a reflection of the earliest possible date of return to play as per the **return to play** protocol (McCrory et al).[15] In the event that the season ended and no further follow-up was available, the final date from the weekly exposure form was used as the final date of time loss.

Evaluation of Risk Factors for Concussion:

Previous history of concussion was defined based on a self-reported "yes" or "no" answer to the question: "Have you ever had a concussion or been 'knocked out' or 'had your bell rung'?" on the preseason baseline questionnaire. Additional risk factors included self-reported sex (male/female), height, weight, year of play ($1^{st}/2^{nd}$ year of play in Bantam; $1^{st}/2^{nd}/3^{rd}$ year of play in Midget), position of play

(forward, defense, goalie), injury in the year prior to the season, and family history of headache. The number of symptoms at baseline, symptom severity score, Standardized Assessment of Concussion score (SAC) and Balance Examination Score (BES) were also evaluated as risk factors for concussion.

Analyses:

Baseline characteristics were summarized (proportions for categorical data, medians and Interquartile ranges (IQR) for numerical data). The primary objectives were assessed using crude injury rates (calculated as the number of concussions/100 players) and rates for concussion and concussion with time loss of greater than 10 days (number of concussions/1000 player-hours). A univariate Poisson regression analysis was conducted to highlight potential risk factors (sex, age group, previous concussion, height, weight, symptoms, previous injury, position, year of play, Sport Concussion Assessment Tool Scores). Poisson regression analysis using backward elimination, including adjustment for clustering by team and offset for exposure hours of participation was used to evaluate rates of concussion and rates of concussion with time loss of greater than 10 days between males and females **while adjusting** for covariates of previous history of concussion and age group. Time from medical clearance to return to sport, by sex, for first concussion was evaluated using a Kaplan-Meier curve.

Results:

Fifty-four teams were approached to participate and 44 teams agreed to participate. An inclusive sample of 854 players who were playing on these teams were approached to participate. (See Figure 1) A total of 778 elite ice hockey players ages 13-17 years (N=44 teams; 31 in Calgary and 13 in Edmonton) participated in this study. Most participants were male (n=659, 84%), with 119 female players (16%) included in the cohort. Participants included 241 (31%) Bantam players (13-14 years of age) and 537 (69%) Midget players (15-17 years of age). Eight players who were on one of the study teams at baseline were subsequently cut from the roster and played on a lower level team. As these individuals could be called up during the season to play on a participating team, they remained in the study. It was assumed that their exposure would be similar to the players on the team from which they were cut, so this was imputed based on mean team exposure hours for these players.

Insert Figure 1

Baseline demographic information for all participants is outlined in Table 1. A previous history of concussion was reported by 39.1% (n=304) of the sample, with 249 players (32.0%) reporting one previous concussion, 48 players (6.2%) reporting two previous concussions, six players reporting three previous concussions (0.8%) and one individual reporting four previous concussions (0.1%). Of those reporting previous concussions, four (1.3%) reported ongoing difficulties with memory, 16 (5.3%) reported ongoing difficulties with dizziness and 43 (14.1%) reported ongoing persisting headaches attributed to their past concussions.

Insert Table 1

Concussions rates by sex

A total of 143 concussions occurred during the season of play. One hundred and thirty-one players sustained one concussion and six players sustained two concussions. After adjusting for cluster by team, the concussion incidence rate was 17.60 (95% CI; 15.09, 20.44) concussions per 100 players. The concussion incidence rate was 1.31 (95% CI; 1.09, 1.57) concussions per 1000 player hours. Rates of concussion in males and females were not found to be **significantly** different in this study (Table 2).

Insert Table 2

Risk factors for concussion and for longer recovery

Unadjusted Univariate analysis

The following output relates to estimates on a univariate level, adjusting only for cluster by team and offsetting for exposure hours. The rate of concussion was not significantly different between males and females ($IRR_{Concussion}$=0.95; 95% CI 0.71-1.25 and $IRR_{Timeloss>10days}$ = 0.99; 95% CI; 0.61, 1.62) or between Bantam and Midget players ($IRR_{Concussion}$=0.96, 95%CI: 0.66-1.40 and $IRR_{Timeloss>10days}$ = 0.86; 95% CI 0.57-1.27). Individuals who reported an injury in the year prior to the season had a 1.51 (95% CI; 1.06, 2.17) times higher rate of concussion with a time loss of greater

than 10 days compared to individuals who did not report an injury in the year prior to the season. Individuals reporting a greater number of symptoms at baseline (SCAT2) had, **on average,** a greater rate of concussion and concussion with > 10 day time loss [IRR=1.05 (95% CI; 1.01, 1.10) and 1.07 (95% CI; 1.03, 1.12) respectively]. Individuals with a greater symptom severity score at baseline (SCAT2) had a higher rate of concussion [IRR=1.03 (95% CI; 1.01, 1.04)] and concussion with > 10 day time loss during the season of play [IRR=1.03 (95% CI; 1.01, 1.05)] (Table 3).

Insert Table 3

Sex as a risk factor for concussion:

Multiple variable analysis

An exploratory multiple variable Poisson regression analysis including adjustment for age group, previous history of concussion, and adjusted for clustering by team and offset for exposure hours was used to evaluate sex as a risk factor for concussion. Based on this multiple variable analysis, there was no significant difference in concussion rate between males and females [IRR=1.01 (95% CI; 0.76, 1.34) p=0.93] or concussion with time loss of greater than 10 days [IRR=1.08 (95% CI; 0.67, 1.75)].

Recovery from concussion:

The median time loss from concussion was 17 days (0-120) for the first concussion and 10 days (7-130) for the second concussion (n=6). Thirty-seven of all

concussions (26%) had a time loss of 10 days or less. Seventy four percent (n=106) of all concussions had a time loss of > 10 days, with 20% (n=28) having a time loss of greater than 30 days. Three players sustained two concussions with a time loss of greater than 10 days and 100 players sustained one concussion with a time loss greater than 10 days. Two players had a concussion with a time loss of greater than 90 days (Table 4 and Figure 1). The survival curves examining time to clearance to return to play for males and females crossed at several time points. As such we can't conclude that there is a difference between males and females in time to recovery and we were unable to perform a Log Rank to evaluate a difference.(Figure 1) For five concussions (3.5%), time loss was estimated based on the last date of follow-up plus seven days to represent the earliest possible date of return to activity. For two concussions (1.4%) that had not resolved by the end of the season, time loss was recorded as the last date indicated on the weekly exposure form.

Insert Table 4

Insert Figure 2

Discussion:

This study included 778 elite youth ice hockey players (84.7% male), all of whom were playing in the most elite divisions in their age group. The concussion incidence rate [IR=1.31 concussions per 1000 players hours (95% CI; 1.09, 1.57)] observed in this cohort was higher than that previously reported for the same league (IR=0.79; 95% CI 0.55-1.31 concussions/1,000 player hours),[16] but the previous estimate

included all levels of play. However, the rate of concussion with time loss of >10 days [1.08 (95% CI; 0.67, 1.75) concussions/1000 player hours in adolescent males] was higher than the previously reported rate of 0.28 (95% CI; 0.15-0.53) concussions/1000 player hours.[17] This higher rate may be reflective of more conservative medical clearance decisions pertaining to return to play, as per recent consensus guidelines.[3]

Of interest, the overall rate of concussion and concussion resulting in time loss of > 10 days were not found to be different in male and female players, despite rules prohibiting body checking in the female leagues. In collegiate athletes, a similar risk of concussion was also observed in male (body checking) and female (non-body checking) leagues over multiple years of participation [7.91 (95% CI, 6.87-8.95) and 7.50 concussions (95% CI, 5.91-9.10) per 10,000 athlete exposures respectively].[6] Body checking is consistently reported as the primary mechanism of injury in ice hockey, and there is substantial literature demonstrating up to a four-fold greater risk of concussion associated with participation in body checking leagues.[17 18] It could, therefore, be hypothesized that women's leagues, which allow body contact but not body checking, would confer a protective effect. The similar incidence rate between males and females suggests that either females may be more susceptible to concussions from the lesser forces associated with body contact, or that there are distinct mechanisms of injury between male and female leagues. Alternatively, females may be more likely to report concussions, which is supported by findings of increasing concussion incidence over the years in women's ice hockey as compared to men's.[17 18] Further study is clearly warranted to better understand the risk of

concussion and mechanisms by which these injuries occur. Studies employing methodologies such as video analysis and biomechanical modeling may provide insight into potential sex differences.

In the present study, 80% of players were medically cleared to return to play within 30 days of injury. This is similar to recent estimates of recovery in youth and high school football.[19] However, in 2011, Meehan et al. found that only 2.8% of high school athletes reported concussion symptoms for greater than one month following injury.[20] Mean times to recovery in collegiate male and female ice hockey players have also been reported to be lower, varying between 6.67 and 9.96 days in the 2004-2009 seasons.[21] Female middle school soccer players who have suffered a concussion have been reported to have a median symptom duration of only 4.0 days.[22] It may be that a greater awareness of concussion and more cautious management has been undertaken in recent years, resulting in a longer time loss from play in more recent studies. For example, better adherence to a graduated return to play protocol would result in longer time to recovery because individuals would take a minimum of 24 hours to progress through each of the six steps of graded exertion recommended by current best practice guidelines.[3]

Limitations:

This study employed a previously validated prospective injury surveillance system, but it is possible that some concussions were unreported. Yet, as each team had a therapist monitoring for concussions and the reported incidence was high, we expect that this potential underreporting was minimized. If there were concussions

that went unreported, the true incidence of concussion may be underestimated in this study.

Individuals reporting a greater number and intensity of symptoms at baseline were at an increased risk of concussion. It may be that individuals who are more likely to report symptoms are also more likely to report concussions, thus potentially overestimating the association between the presence of symptoms and risk of concussion**. A previously validated injury surveillance system was implemented. However, it is possible that some of the risk factors of interest may have varied over time (e.g. position of play, subcomponent scores from the SCAT).**

Conclusions:

Concussion is a common injury in elite youth ice hockey players ages 13-17 years. **Time loss greater than 10 days was reported in 74% of cases (106/143) and 20% (n=28) had time loss of greater than 30 days.** The concussion rate did not differ between male and female players, despite rule differences allowing body checking in male leagues. Players with a previous history of concussion, greater number of baseline symptoms, and greater intensity of symptoms at baseline were at an increased risk of concussion. Future research examining potential differences in mechanism of concussion injury between males and females is recommended. The high rate of concussion reported in this study speaks to the need for future work to identify prevention strategies for concussion in youth athletes.

References:

1. McCrory P, Meeuwisse W, Dvorak J, et al. Consensus Statement on Concussion in Sport - The 5th International Conference On Concussion in Sport held in Belin, October 2016. *British Journal of Sports Medicine.* 2017;51(11):838-47.
2. Emery C, Meeuwisse W. Injury Rates, Risk Factors, and Mechanisms of Injury in Minor Hockey. *Am J Sports Med* 2006;34(12):1960-69.
3. McCrory P, Meeuwisse W, Aubry M, et al. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. *British Journal of Sports Medicine* 2013;47:250-58.
4. Zemek R, Barrowman N, Freedman SB, et al. Clinical Risk Score for Persistent Postconcussion Symptoms Among Children With Acute Concussion in the ED. *JAMA* 2016;315(10):1014-25.
5. Barlow KM, Crawford S, Stevenson A, et al. Epidemiology of postconcussion syndrome in pediatric mild traumatic brain injury. *Pediatrics* 2010;126(2):e374-81. doi: 10.1542/peds.2009-0925 [published Online First: 2010/07/28]
6. Zuckerman SL, Kerr ZY, Yengo-Kahn A, et al. Epidemiology of Sports-Related Concussion in NCAA Athletes Fro 2009-2010 to 2013-2014 Incidence, Recurrence and Mechanisms. *Am J Sports Med* 2015;43:2654-62.
7. Black AM, Sergio LE, Macpherson AK. The Epidemiology of Concussions: Number and Nature of Concussions and Time to Recovery Among Female and Male Canadian Varsity Athletes 2008-2011. *Clinical Journal of Sport Medicine* 2017;27(1):52-56. doi: 10.1097/JSM.0000000000000308

8. Statistics Canada. Canadian Heritage Sport Participation 2010. Research Paper, 2013.
9. Canada H. Hockey Canada 2014-2015 Annual Report [Available from: http://cdn.agilitycms.com/hockey-canada/Corporate/About/Downloads/2014-15_annual_report_e.pdf accessed July 28 2016.
10. Harmon KG, Drezner JA, Gammons M, et al. American Medical Society for Sports Medicine positiion statement: concussion in sport. *British Journal of Sport Medicine* 2013;47:15-26.
11. Pfister T, Pfister K, Hagel B, et al. The incidence of concussion in youth sports: a systematic review and meta-analysis. *British Journal of Sport Medicine* 2016;50(5):292-97.
12. Mrazik M, Perra A, Brooks BL, et al. Exploring Minor Hockey Players' Knowledge and Attitudes Toward Concussion: Implications for Prevention *J Head Trauma Rehabil* 2015;30:219-27.
13. Meeuwisse WE, Love EJ. Development, implementation and validation of the Canadian Intercollegiate Sport Injury Registry. *Clin J Sport Med* 1998;8(3):164-77.
14. Kang J, Yuan Y, Emery C. Assessing remedies for missing weekly exposure in sport injury studies. *Injury Prevention.* 2014;20(3):177-82. doi: 10.1136/injuryprev-2012-040537.

15. McCrory P, Meeuwisse W, Johnston K, et al. Consensus Statement on Concussion in Sport 3rd International Conference on Concussion in Sport Held in Zurich, November 2008. *Clin J Sport Med* 2009;19:185-200.
16. Emery C, Kang J, Shrier I, et al. Risk of injury associated with bodychecking experience among youth hockey players. *CMAJ.* 2011;183(11):1249-56. doi: 10.1503/cmaj.101540 [published Online First: 2011/06/22]
17. Emery C, Kang J, Shrier I, et al. Risk of Injury Associated with Body Checking Among Youth Ice Hockey Players. *JAMA* 2010;303(22):2265-72.
18. Emery C, Hagel B, Decloe M, et al. Risk factors for injury and severe injury in youth ice hockey: a systematic review of the literature. *Injury Prevention* 2010;16:113-18.
19. Kerr ZY, Zuckerman SL, Wassermann EB, et al. Concussion Symptoms and Return to Play Time in Youth, High School and college American Football Athletes. *JAMA Pediatrics* 2016;170(7):647-53. doi: 10.1001/jamapediatrics.2016.0073 [published Online First: May 02, 2016]
20. Meehan WP, 3rd, d'Hemecourt P, Collins CL, et al. Assessment and management of sport-related concussions in United States high schools. *The American Journal of Sports Medicine* 2011;39(11):2304-10. doi: 10.1177/0363546511423503 [published Online First: 2011/10/05]
21. Covassin T, Moran R, Elbin RJ. Sex Differences in Reported Concussion Injury Rates and Time Loss From Participation: An Update of the National Collegiate Athletic Association Injury Surveillance Program From 2004-2005 Through 2008-2009. *J Athl Train* 2016;51(3):189-94.

22. O'Kane JW, Spieker A, Levy MR, et al. Concussion Among Female Middle-School Soccer Players. *JAMA Pediatrics* 2014;168(3):258-64.

Figure Legend:

Figure 1. Summary of team and player recruitment

Figure 2. Kaplan Meier curve for time to medical clearance in males and females